Communication Skills I: Extended Abstract

Cycling and Aerodynamics

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Abstract

The importance of aerodynamic resistance has been always recognized by cyclists and engineers, who over many years have been trying to find ways to reduce the aerodynamic drag. Therefore, the aerodynamics plays an important role and it could influence the result of a race. Bert Blocken and his research team from the Eindhoven University of Technology in order to understand how air resistance behaves, the aerodynamic drag of two drafting cyclists were simulated. Three different CFD simulations in terms of the rider position for different separation distance were made: upper position, dropped position and time trial position and distance from 0.01 m to 1m. All the simulations were supported by wind tunnel measurement and all the drafting results were compared with a single cyclist simulation.

Keywords: Aerodynamics; cyclist; drafting; drag; drag reduction; trailing car; trailing cyclist; time-trial

1. Introduction

Aerodynamics plays an extremely important role in cycling. It has been found that a t typical racing speed of about 15 m/s, the resistance due to drag is about 90% of the total resistance. The most important tools used in the industry in order to understand and improve aerodynamics are wind tunnels and CFD. While most of the aerodynamic studies of cycling are focused on the aerodynamic drag of a single cyclist, several efforts have also been made to evaluate the effects of drafting techniques. The drafting is a technique which can be explained as two or more cyclists ride close behind each other to reduce aerodynamic drag. The aim of this project is to quantifying the effects of two drafting cyclists considering different distance between them and paying special attention not only to the benefit of the trailing cyclist but also for the leading one.

2. Followed procedure

2.1. Geometry, Domain, and boundary conditions

The used geometry consists on the body of two cyclist obtained via high resolution 3D scanning (being the chassis of the bikes neglected). As the purpose is to study the effects of different positions and distances, the cyclists were scanned in UP (upper position), DP (dropped position) and TTP (time-trial position) and then were place in a squared computational domain of L x W x H =20.9m x 6m x 7m at different separation distances (0.01 m, 0.25 m, 0.50 m, 1.00 m).

At the inlet section of the domain a uniform velocity of 15m/s is prescribed, on the outlet the ambient pressure is imposed while on the rest of the surfaces a non-slip condition is applied.

2.2. Mesh discretization

In order to obtain reliable results, prismatic cells with size 30 μm are used in the regions closer to the surfaces where the boundary layer takes place. Further away from the cyclist surfaces tetrahedral elements are used with an average cell size of 0.03 m. The total number of elements is of the order of $12 \cdot 10^6$.

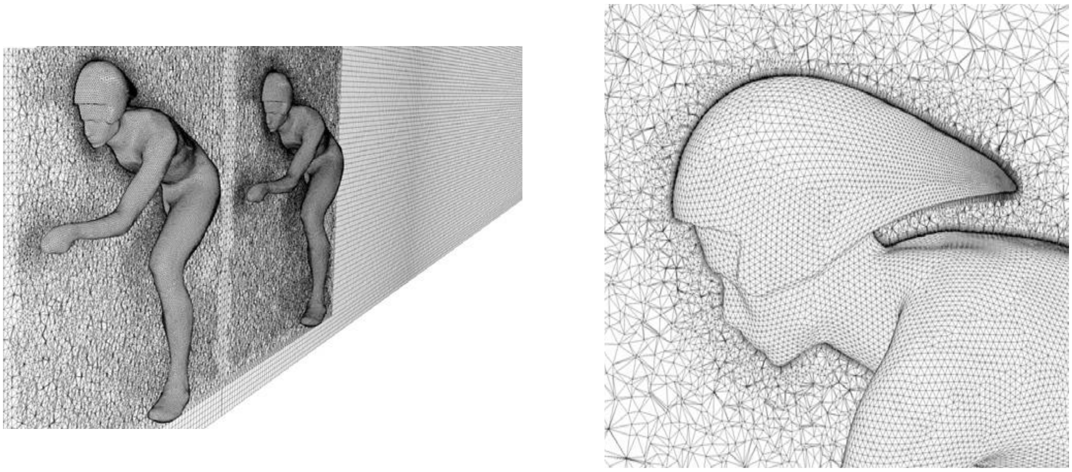

Fig. 1. Space Discretization. (a) General overview; (b) Close to surface detail.

2.3. Solver settings

The simulations have been carried out using Ansys fluent 12 and k-ε modeling for the turbulence. The achieved residuals are of order 10^{-4} for continuity equation, 10^{-7} for momentum equation, 10^{-6} for turbulent kinetic energy, and 10^{-4} for turbulence dissipation rate.

3. Results

3.1. Drafting cyclist

From the results of the simulations of a single cyclist and two cyclist in a row, it can be obtained the drag reduction in the case of two cyclist drafting. It's important to recall that for the study it was considered that both cyclists adopted the same positions.

In figure 2a it can be seen that the less aerodynamic position both cyclist adopt, more drag reduction the cyclist behind takes, and that this effect decreases with the distance; while in figure 2b happens quite the opposite being that the leading cyclist gets more reduction as it takes a more aerodynamic position, but still the effects decreases with the distance

We can also see that the drag reduction is however much more significant for the trailing cyclist than for the leading one, although it comes unexpected that leading cyclist would receive any benefit at all.

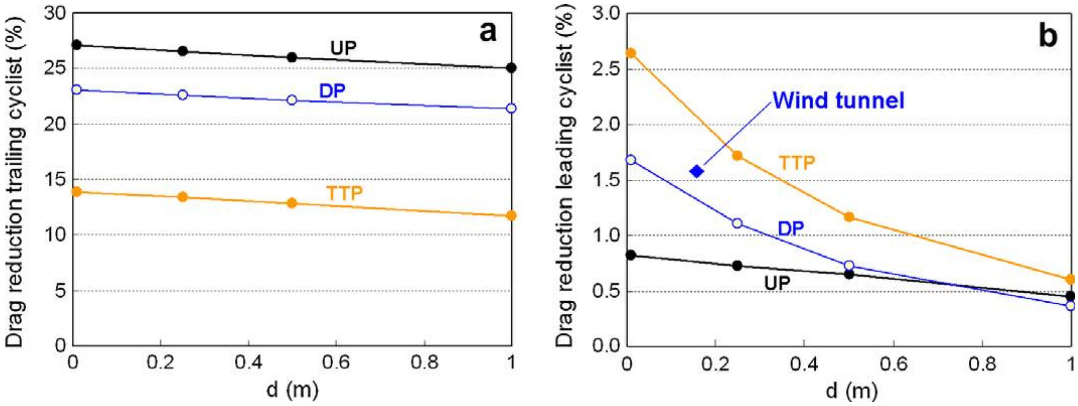

Fig. 2. Drag reduction experienced by (a) trailing cyclist and (b) leading cyclist.

From the pressure contour in Figure 3 it can be understood how the phenomena stated previously works. In general we can see that the drag on a cyclist is the contribution of an over-pressure in front of it pushing back and an under-pressure pulling from behind. This explains the unexpected behavior of the leading cyclist getting a reduction on the drag, as the trailing fills in the space behind the leading one, and so the effects of the pulling decrease.

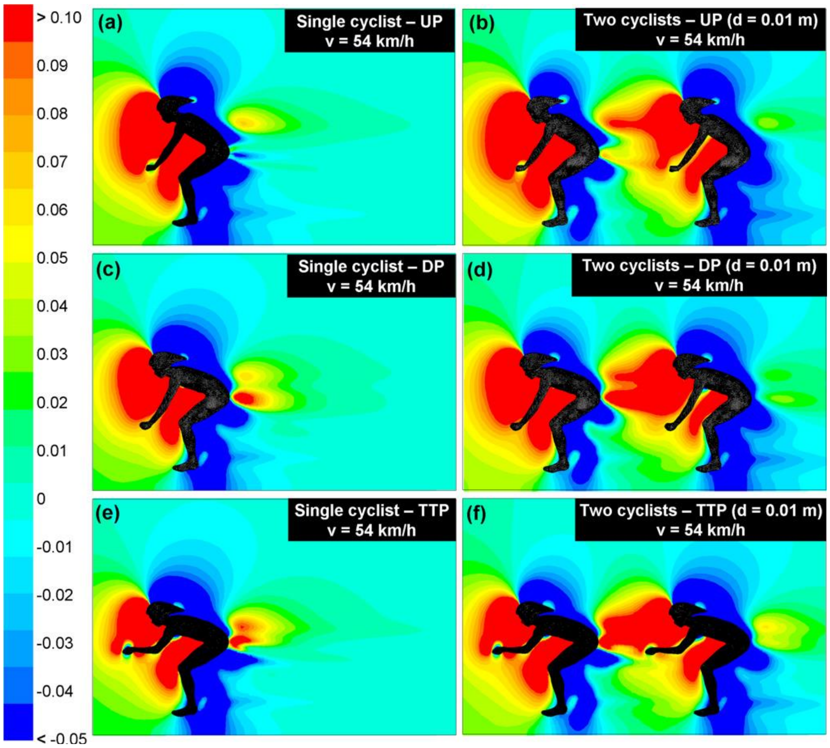

Fig. 3. Pressure coefficient C_p map

3.2. Drafting car

Related with those simulations, the same main author also performed a study of the drag effects of a trailing car, and for this case it was proved that the effects can extend up to 30 meters. At this point it's important to consider that for single time trial competition the team's car is expected to be further than 10 meters, but often this condition is not met such that the drag reduction on the cyclist can be considerable.

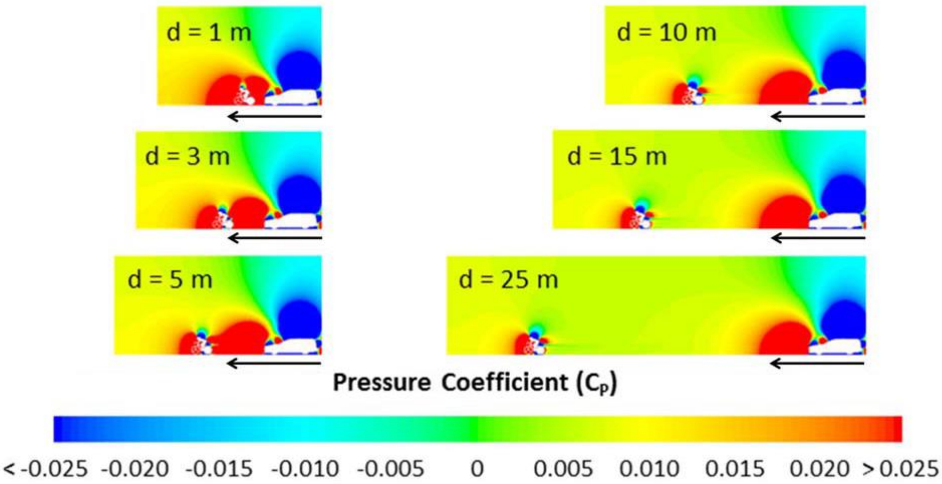

Fig. 4. Pressure coefficient C_p map for a trailing car.

4. Limitations of the study

Although the obtained results are considered accurate enough (even validated using wind tunnel) it is important to consider that the implemented methodology has some limitations as could be:

- Dynamic effects are neglected.
- Drag force of the chassis is out of the computation.
- Two cyclist hardly maintain steady positions.

5. Conclusions

From the results obtained on this work it can be concluded the following:

1. Trailing cyclist gets more drag reduction as both cyclist adopt less aerodynamics position.
2. Leading cyclist gets more drag reduction as both cyclist adopt more aerodynamic position.
3. Drag reduction is more considerable in case of the trailing cyclist.
4. Trailing car effects can extend up to 25-30 meters and induce a drag reduction up to a 3.7%.

References

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